



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

SOME NOTES AND EXPERIMENTS ON *SARCOCYSTIS*
TENELLA, RAILLIET *

JOHN W. SCOTT

In a recent paper on Sarcosporidia encountered in the Canal Zone, Darling (1915) makes the interesting suggestion that the "Sarcosporidia may be side-tracked varieties of some of the Neosporidia of invertebrates which have invaded the musculature of a hospitable though by no means definitive host and are unable to continue further their life cycle and escape from a compromising and aberrant position." Darling thinks the high incidence of infection in cattle, sheep, swine, and horses favors this view, and points out the ease with which such animals may obtain Neosporidia in their food. In this connection the writer has obtained during the past year some data concerning the sheep sarcocyst that appear to favor a similar conclusion. Though the results of the experiments were negative the inferences are nevertheless interesting.

A large percentage of the range sheep of Wyoming are probably infected with *Sarcocystis tenella*. Out of sixty-five sheep examined at different times at a local slaughter house fifty were found infected, or nearly 77 per cent. In some lots approximately 100 per cent. were infected. The parasite presented the general appearance described by Railliet (1895), Alexieff (1911), and others. The stages found usually showed an alveolar structure, a few presented the pansporoblast stage, but none were in the Balbian stage. Some of the largest cysts, and presumably the oldest ones, had the appearance of fading out or undergoing degeneration, and so far as one could observe from living material there was no indication that the parasites ever escape from the muscle of the host. The heart muscle and the esophagus were examined for the cysts, but they were found much more frequently in the heart.

Since the direct observations just mentioned gave no clue to the life history, a preliminary series of experiments was planned to test various hypothetical methods of infection. Smith (1901) has succeeded in getting a direct infection in mice by feeding muscle tissue from infected mice, and the first experiment was to determine if this method would succeed in the case of the sheep sarcocyst. While Smith's experiment might account for a natural transmission of the

* Contribution No. 2 from the Laboratory of Zoology and Parasitology, University of Wyoming. Experiments by aid of Adams Fund.

Sarcosporidia of carnivorous animals, it cannot explain transmission in the sheep, or in other herbivora. Dr. L. D. Swingle, formerly of the University of Wyoming, fed five young lambs pieces of heart muscle containing the sarcocysts. From the time they were born these lambs were fed dry feed in a dry lot and were watered from the city water supply which has its source in deep springs. When the writer examined these lambs at slaughtering time not a single one was infected. Control lambs, kept under the same conditions, were likewise uninfected. This experiment has been repeated with similar results, and it appears to show that the parasites in the sarcocysts are not in a transmissible stage or condition, using the direct method.

Several authors have held the view that an intermediate host is necessary, since the delicate structure of the spores of Sarcosporidia would ill adapt them to withstand the conditions outside of the vertebrate host. For this reason Wasielewski (1896) believes that, as in the case of the malarial parasite, an intermediate host is necessary in order to convey the parasite from one host to another. On this theory, Minchin (1903) suggests three possibilities in regard to infection by Sarcosporidia: (1) The intermediate host is a large carnivore, as the dog, in case of parasites like those of the pig or sheep; (2) after death the parasites are taken up by some carrion-feeding animal, which might be some vertebrate, as bird or mammal, or some invertebrate, as blow-fly or carrion-beetle; (3) the infection might be taken on by some internal parasite, for example, a flatworm or a nematode. Minchin regards the third explanation as unlikely, and I have frequently found lambs with no parasitic worms present, but at the same time infected with Sarcosporidia. He believes the second explanation receives some support from the extremely toxic nature of the parasites themselves, since this would aid in the death of the host.

More recently Minchin and Thompson (1915) have shown that the rat-trypanosome passes through a cycle in the digestive tract of the rat-flea, and that after this period the rat becomes infected either by licking the flea feces or by ingesting the flea. While there is no blood-sucking parasite of the sheep in Wyoming that could perform a similar role for *S. tenella* and at the same time account for the prevalence of this parasite, the object of the following experiment was to test whether digestion by a carnivorous animal (coyote or dog) would render the Sarcosporidia contaminative.

My second experiment, therefore, was essentially a test of Minchin's first hypothesis. On August 28 a young dog was fed liberally on sheep hearts containing sarcocysts and placed in a wire cage where the grass had not been pastured. On August 31 the dog was again fed with infected muscle, and in the afternoon of September 2 he was taken out

of the cage. By this time feces were well scattered over the grass. Water was sprinkled heavily on the grass September 3 and 9 in order to further facilitate contamination. On September 11 two lambs, previously kept in a dry lot, were placed in the cage and left for about thirty-three hours. Again October 1 two more lambs were put in the cage and left for twenty-four hours. A later examination showed that none of these lambs was infected.

Though the experiment is not conclusive, the evidence is against the idea that the digestion of muscle tissue by a carnivorous animal is the normal method by which the Sarcosporidia of the sheep are set free in order that they may be accessible through its own herbivorous habits. Indeed, the comparatively rare occasions on which coyotes and dogs obtain sheep's flesh would hardly account for the frequency with which flocks are infected.

During the summer of 1914 another experiment was tried that is even of more interest, and to a certain extent is a test of the second explanation suggested by Minchin. Two groups of lambs were used. Group one, consisting of twenty-one ewes and eighteen lambs, was allowed to graze in pasture A, where both dry and swampy conditions were present. In this pasture is located a permanent pond fed by seepage water, and the pond overflows except in the dry season into the swamp. The swampy portion of the pasture went dry about mid-summer. Group two, consisting of twenty-five ewes and twenty-three lambs, was allowed to graze in a small dry pasture B, where no water was present except such as fell in the frequent though scanty summer rains. At several times during the summer infected pieces of heart muscle were scattered in the pond in pasture A, and also upon the grass in pasture B. When the lambs were killed 55 per cent. of Group 1 (ten out of eighteen) were found infected, and 21 per cent. (five out of twenty-three) of Group 2. From this result it appeared (1) that lambs may become infected either through water or by eating infected grass; or, (2) which is more probable, the infection was independent of the experiment.

On the assumption that the third experiment gave positive results, it is hard to reconcile the infection of lambs in Group 2 with the results from the first two experiments. For if one does not get positive results by direct feeding of infected muscle, or by feeding grass contaminated with feces after the ingestion of infected muscle, one would not expect any infection where the muscle was simply scattered on the grass. Again, if scattering muscle containing sarcocysts on the grass or in water, and the consequent decay is a necessary condition for infective material, we are confronted with the fact that the natural death and decay of sheep carcasses will not account for all cases of infection. It

therefore appears that the infection which took place under the conditions of the third experiment was independent of the experiment. What other possibilities are left?

If we assume that the sheep is the definite host of *S. tenella* and that no intermediate host is necessary, we must conceive that the parasites are set free in the blood, find their way to the exterior in the excretions, probably in feces or urine, and that in this way food or drink is contaminated. Most authors regard this as extremely improbable and we have already stated that there is no evidence to show that the Sarcosporidia are freed in this way. Again, lambs fed along with ewes in a small dry lot must frequently have the hay contaminated with feces or urine, and yet under these conditions in the experiments no infection has so far occurred. On the other hand, if we consider an intermediate host is necessary, three possibilities arise. We may think of an external blood parasite as being the active agent in transferring the Sarcosporidia from one sheep to another; but in this case no external parasite appears to satisfy all the conditions, and we ought to get transmissions in a dry lot as well as elsewhere. Second, we may think of the intermediate host as feeding upon contaminated feces or urine and later depositing the spores on food or drink of the sheep. We can at once eliminate the matter of drink, for there was no water to be had in pasture B of my third experiment where infection occurred. While certain insects on this hypothesis might possibly account for the infection of both groups of the third experiment, it is probable that control lambs, confined with their ewes in an adjacent dry lot, would also have become infected, and we have already noted that there is no evidence that spores escape in the way suggested. The third possibility would be to assume that the intermediate host is a carrion-feeding animal. But no carrion-feeding vertebrate common to pastures A and B could be discovered. Besides, the heart muscle thrown into the shallow pond in pasture A sank to the bottom, where it was inaccessible to any sort of carrion-feeding animal, especially any insect, that might happen to be present. Minchin's second suggestion, therefore, as a possible method of infection appears to be out of the question.

If, however, the sheep is not the definitive host of *S. tenella*, but the presence of the parasite is more or less accidental, the results of the experiments given are more easily explained. First, it is evident that the conditions for infection are much more favorable in pasture A than in pasture B, though the parasites were acquired in both places. It is therefore well to consider further the difference between the two places and their similarities. In pasture B the grass was rather sparse, flowering plants were few in both numbers and kind, and various flies,

ants, beetles (under cattle dung), mosquitoes, bees (occasionally), grasshoppers, a few moths, and spiders were present. All of these things were present in pasture A, and, besides certain specific water animals, it differed from pasture B in the following particulars: There were more flowering plants, sedges were abundant in the swampy portions, mosquitoes and various flies were very abundant, and bees and moths were more frequently found. Now Erdmann (1910), Minchin (1912), and others look upon the Sarcosporidia as one group of Neosporidia, on the basis of what is already known in regard to their development and structure. If we accept their conclusions, and if according to Darling's suggestion the Sarcosporidia are aberrant Neosporidia, and infection of herbivora is acquired by accidental ingestion of invertebrate hosts or by the ingestion of the droppings of such hosts upon flowers or leaves, we can readily understand how infection took place in both pastures and how the percentage of infection in pasture A greatly exceeded that in pasture B. Further experiments are now in progress which will test the question of whether *S. tenella* is in reality only an aberrant form of one of the Neosporidia.

SUMMARY

To sum up this paper, one may say that the experiments are chiefly important for their negative significance. Infection with *S. tenella* failed to occur, (a) as the result of feeding infected muscle, (b) as the result of eating grass contaminated with feces from a carnivorous animal previously fed on infected muscle, and (c) by allowing infected muscle to decay either on dry grass or in a pond. The apparently positive results of the third experiment are best explained as due to conditions independent of that experiment. All of the evidence favors the view that the sheep is not the definitive host of *S. tenella*, and therefore is in accord with Darling's suggestion that the muscle parasites of vertebrates are aberrant forms.

REFERENCES CITED

- Alexieff, A. 1911. Sur la morphologie de la sarcosporidie de mouton (*Sarcocystis tenella* Railliet), Soc. de Biologie, 71, 397.
- Darling, S. T. 1915. Sarcosporidia Encountered in Panama, Jour. of Parasitol., 1, 115.
- Erdmann, Rh. 1910. Die Entwicklung der *Sarcocystis Muris* in der Muskulatur, Sitzungsab. d. Gesellsch. Naturf. Freunde, zu Berlin.
- Minchin, E. A. 1903. Sporozoa: Treatise on Zoology, Ed. by E. R. Lankester, Part 1, fasc. 2.
1912. An Introduction to the Study of Protozoa, London.
- Minchin, E. A., and Thomson, J. D. 1915. The Rat-Trypanosome, *Trypanosoma lewisi*, in Its Relation to the Rat Flea, *Ceratophyllus fasciatus*, Qrtly. Jour. Micr. Sci., London, 601.
- Railliet, A. 1895. Traite de zoologie médicale et agricole, Ed. 2, pp. 150-157.
- Smith, Th. 1901. The Production of Sarcosporidiosis in the Mouse by Feeding Infected Muscular Tissue, Jour. Exp. Med., 6.
- Wasielewski, V. 1896. Sporozoenkunde. Jena, pp. 119-127.